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# Determining Airtanker Delivery Performance Using a Simple Slide Chart-Retardant Coverage Computer

Charles W. George

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**RETARDANT COVERAGE COMPUTER**  
GUM-LIKE RETARDANT

Coverage (gal/100ft<sup>2</sup>) 0.5  
Drop Height (ft) 300 400

Type of Aircraft:  
CDF/Hemet Valley  
Tanked S2F  
800 Gallons  
70, 71

USDA FOREST SERVICE  
INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION  
NORTHERN FOREST FIRE LABORATORY, MISSOULA, MT

(GUM-LIKE) Phos-Chex XA, Gelgard, Tenogum & Gum thickened Fire Trol 931(LC)

Coverage Level	Fuel Model (1000 NERBS)	Description
1	A. L. S.	Annual and Perennial Western grasses, Lunds
2	C. H. P. U.	Tall grasses, Conifer (with grasses) intermediate and for woody shrubs (understorey)
3	E. R.	Hardwoods (winter and summer)
4	K. P. N. T.	Light slash (conifer or hardwood) intermediate brush (green), Sawgrass, Western woody shrubs
5	G.	Shoreline conifer (heavy dead litter)
6	D. O. P.	Southern Rough, Alaska Black Spruce, Intermediate slash (four)
Greater than 6	B. I. J. O.	California mixed chaparral, Medium and heavy slash, High Pocosin

For reports or other information, contact the nearest Forest Service office.  
1. Coverage is based on a 1000 NERBS fuel model. For other fuel models, use the appropriate coverage factor.  
2. Coverage is based on a 1000 NERBS fuel model. For other fuel models, use the appropriate coverage factor.

INSTRUCTIONS: Select coverage level, drop distance and drop height, read line length and delay time for appropriate drop distribution or retardant.

Line Length (ft)	Delay (s)
100	1.0
125	1.25
150	1.5
175	1.75
200	2.0
225	2.25
250	2.5
275	2.75
300	3.0
325	3.25
350	3.5
375	3.75
400	4.0
425	4.25
450	4.5
475	4.75
500	5.0
525	5.25
550	5.5
575	5.75
600	6.0
625	6.25
650	6.5
675	6.75
700	7.0
725	7.25
750	7.5
775	7.75
800	8.0
825	8.25
850	8.5
875	8.75
900	9.0
925	9.25
950	9.5
975	9.75
1000	10.0

## THE AUTHOR

**CHARLES W. GEORGE** graduated from the University of Montana in 1964 in forest engineering. He received his M.S. degree at the University of Montana in 1969. In 1965, he joined the Intermountain Station's Northern Forest Fire Laboratory staff in Missoula, Mont., where he has conducted studies related to prescribed fire, pyrolysis and combustion, fire retardant chemicals, and aerial fire retardant delivery systems. He is currently the leader of the Fire Control Technology research work unit.

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## RESEARCH SUMMARY

Retardant coverage computers/slide charts have been developed for many aircraft and tank and gating systems in the national airtanker fleet. The computers indicate retardant delivery performance for specific tank and gating systems, and recommend coverage levels for various fuel/fire situations. The computers summarize data found in published airtanker performance guides and provide additional information regarding safe drop heights. The computers provide a simple, inexpensive method for identifying important performance characteristics of different airtankers and for selecting the most effective drop configurations. This report discusses development of the computer and provides instructions and examples of use.

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# Determining Airtanker Delivery Performance Using a Simple Slide Chart-Retardant Coverage Computer

Charles W. George

## INTRODUCTION

To employ airtankers most efficiently, fire managers and air attack personnel must recognize the performance characteristics of many different types of airtankers and tank and gating systems. The airtanker pilot and lead plane pilot must select the volume of retardant to be dropped, the drop configuration, and the release interval for multi-compartment drops for the specific fuel and fire situation. To aid personnel, airtanker performance guides have been developed. Like an instruction manual for an instrument, the guides present performance data on specific aircraft and tank and gating systems, for alternative drop configurations, release sequences, and drop heights (George 1975a; Swanson and others 1976).

The national airtanker fleet currently numbers more than 100 airplanes incorporating about 50 different tank and gating systems, each having specific performance characteristics. Airtanker performance guides have been developed for many of the aircraft and delivery systems, and additional guidelines are planned for those not now covered. Although the performance guides are available and relatively easy to use, there is a need for a simple, inexpensive reference that can be used in real-time to identify and delineate primary performance. To satisfy these goals, airtanker performance "slide charts" (retardant coverage computers) have been developed (fig.1).

The retardant coverage computers allow quick determination of the best drop configuration for a given drop height and desired retardant coverage level for both waterlike and gum-thickened retardants. The computers provide the correct time interval between compartment releases for trail

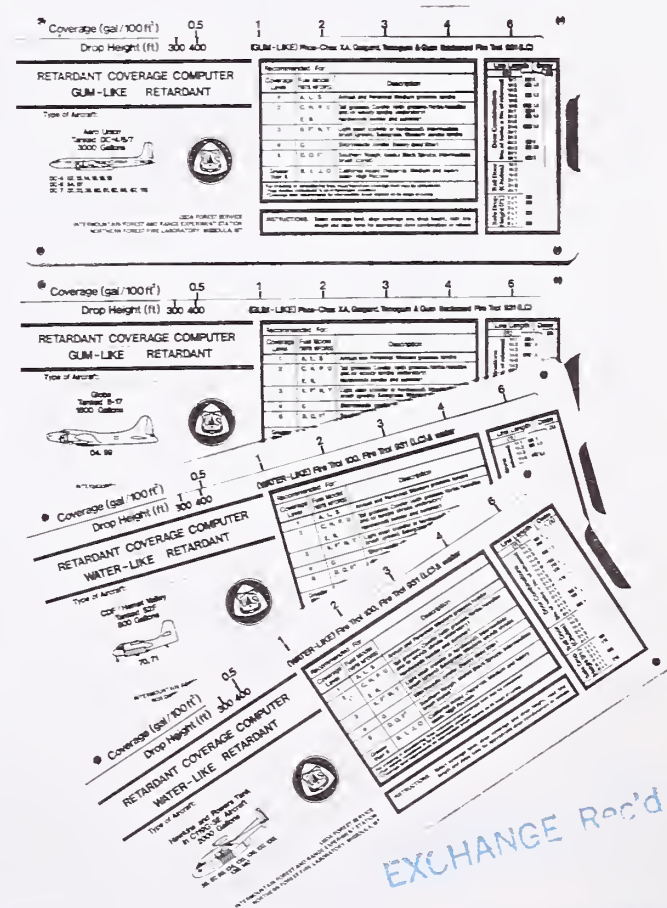


Figure 1.--Retardant coverage computers for specific airtankers have been developed to depict performance under a variety of conditions.

or sequential drops and the maximum length of line that can be expected at selected retardant coverage levels. The coverage computers also provide an estimate of the safe drop height for various retardant volumes to avoid injury to men or damage to equipment on the ground. Individual computers are necessary for each type of delivery system because of the large amount of data involved: retardant type, drop heights, retardant coverage levels, drop combinations, individual trail drops, door delay intervals, and safe drop heights. The amount of data and the method of derivation render individual coverage computers more practical than other approaches, for example, the handheld programmable calculator.

The purpose of this report is to describe the retardant coverage computer and the information it contains, and to illustrate its application.

## RETARDANT COVERAGE COMPUTER INFORMATION

### Aircraft and Tank and Gating System Description

The ability of air attack personnel to use airtankers most efficiently has been hampered by the large number of different aircraft and tank and gating systems. Due to the mobility of airtankers and practices of deployment, an air attack specialist may frequently encounter airtankers with which he is unfamiliar. Knowledge of specific tank and gating systems (i.e., number of compartments, availability of trail release systems, general performance) is necessary to employ them efficiently. Because of these factors and the magnitude of differences in performance (even between the same type of aircraft) separate performance guides and coverage computers have been developed for each type of tank and gating system. Thus, one model of airplane may require several different coverage computers.

Each coverage computer provides for the identification of the aircraft type, tank and gating system, and all the individual aircraft for which it may be applicable. Each coverage computer is developed for a particular tank volume released. The volume for which a computer was developed is given as part of the identification information. Figure 2 illustrates the identification information shown in a window in the coverage computer for an Aero Union tanked DC-4/6/7 carrying 3,000 gallons. All Aero Union tanks for the DC-4, DC-6, and DC-7 are identical in design and construction although not all DC-4, DC-6, and DC-7's can carry 3,000 gallons. (The maximum retardant an aircraft can carry is determined by the characteristics of the specific aircraft.) Delivery performance differs with retardant capacity. Thus, for this tank and gating system, performance guides were developed for capacities from 1,800 to 3,000 gallons, in 200-gallon increments. The appropriate guide or coverage computer is selected based on the retardant volume being carried (which may vary with the performance of the aircraft or by the density-altitude, airport restrictions at the operating base, or the contract requirements). The 1,800- and 2,000-gallon Aero Union tanked DC-4/6/7 coverage computer will usually be used for the DC-4. The remaining computers would be used for DC-6 and DC-7 aircraft, depending on each aircraft's performance and conditions of use.

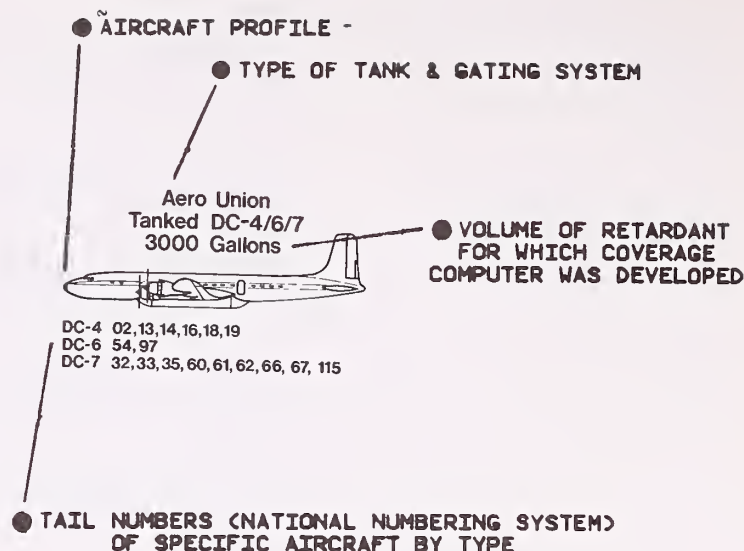


Figure 2.--Example of identification information shown in the I.D. window of a Retardant Coverage Computer.

The numbers below the aircraft profile in the identification window refer to the tail numbers for specific aircraft. The numbers are assigned as airtankers are approved by the Interagency Airtanker Screening and Evaluation Board. Each aircraft (specific serial number and N number) receives a number that is to remain with that aircraft as long as it is in service (remains available as an airtanker in the national fleet). In the illustration discussed above and shown in figure 2, tankers 54 and 97 can be identified as DC-6 aircraft equipped with an Aero Union tank. The performance guide and coverage computer applicable is then determined by the retardant volume being carried. If the volume carried is considerably different from that for the existing guide (200 gallons or more), the performance data will not be applicable and must be adjusted. This can be done as a percentage of volume adjustment or by using the more detailed "Procedures to Adjust Airtanker Performance Guides for Downloaded Operations" (Luedecke and Swanson 1979a, 1979b).

### Type of Retardant

The performance of retardant depends upon the physical or rheological properties (George 1975b; Andersen and others 1974a, 1974b, 1976). Retardants that have a high effective viscosity and elasticity over the range of shear rates encountered during fluid release, deformation, and breakup have been shown to yield a larger mean droplet size within the retardant cloud. Larger droplet size results in greater retardant recovery due to reduced evaporation and drift. The clouds of larger retardant droplets are considerably more wind resistant and provide patterns of higher average concentration. In the development of the airtanker performance guides (Swanson and others 1975, 1977), retardants were grouped into classes based on their delivery performance: **gumlike** retardants usually containing guar gum thickening agents that yield a high effective viscosity and elasticity, and **waterlike** retardants that exhibit little or no elasticity and a low effective viscosity (although a high apparent viscosity may be present, as the case with clay-thickened Fire-Trol 100).

The performance of the two classes of retardant in the pattern simulation model (PATSIM), used to generate the data contained in the retardant coverage computer, is governed by a rule for the percentage of retardant recovered (Swanson and others 1977). The difference in retardant recovery in turn results in differences in the down-range and cross-range retardant distributions (pattern lengths and widths at various coverage levels). The use of a constant rule for percentage recovery for all aircraft results in a conservative estimate of differences between the two types of retardant in the performance guides and retardant coverage computers. (Further discussion of the nature of the rules and the pattern simulation can be found in the previous reference documents on the development of the performance guidelines.)

The performance for gumlike and waterlike retardants for a given tank and gating system is displayed physically on separate sides of the retardant coverage computer. The retardant type is shown in bold print through a window spelling out “**GUM-LIKE**” or “**WATER-LIKE**” retardant. The specific retardant formulations for each type retardant are also printed on the slide-chart insert in the “**DROP-HEIGHT**” window (to be discussed later). The formulations as categorized by drop performance are:

- (WATER-LIKE)

Fire-Trol 100, Fire-Trol 931 (LC), and water
- (GUM-LIKE)

Phos-Chek XA, Gelgard, Tenogum, and Gum-thickened Fire-Trol 931(LC)

A comparison of the difference in performance between the waterlike and gumlike retardants can be made for any selected drop height, retardant coverage level, and drop configuration by simply flipping over the retardant coverage computer without changing the slide. For example:

*A Transwest tanked DC-7 carrying 3,000 gallons of retardant will provide the following line lengths at a retardant coverage level of 3 gallons/100 ft<sup>2</sup> (gpc) from a drop height of 300 feet:*

Drop configuration (compartments released)	Length of line in feet at 3 GPC		Percent increase in length for gumlike over waterlike retardant
	Gumlike	Waterlike	
1	80	35	129
2	155	130	19
3	190	160	19
6	290	235	22

Examination of the above example and similar performance data for other drop configurations, drop heights, and retardant coverage levels will illustrate that the difference in performance for the two types of retardant varies with the type of tank and gating system (flow rate), drop size, drop configuration, and drop height. The comparison will also indicate that the performance (line length) can differ from several percent to several fold.

### Drop Height

Airtanker performance guides provide delivery performance data over a range of drop heights usually from 100 to 500 feet. The drop height is the **tape line altitude above the ground level**. Fuels will modify the pattern as retardant droplets within the cloud impact the fuel, are retained, reflected, or continue to drip from the fuel. A base-line performance must be established, however, to permit comparisons of tank and gating systems, retardants, effects of various drop conditions, etc. The performance guides and coverage computers can be thought of as providing a pattern description at the moment the retardant cloud enters the canopy or fuel complex. The effect of the fuel complex on the pattern (the resulting pattern on the ground) may be large (for dense heavy fuels) or insignificant (for light grass or brush fields). Retention of retardant by the aerial fuel and its impact on the retardant levels needed to slow or stop a fire in a given fuel system were considered when deriving the recommended retardant coverage levels and will be discussed in a subsequent section of this paper.

The effect of the fuel complex on retardant interception and final distribution is a function of the angle of entry of the retardant and its characteristics (droplet sizes, velocities, rheological properties, etc). Aerial fuels can be penetrated by (1) dropping from relatively high altitudes, which allows complete retardant breakup and vertical fall through the vertical openings of most stands, or (2) driving the retardant through the canopy by low-level attack. The most uniform coverage and efficient retardant distribution is generally attained when near-vertical fall of the retardant occurs and minimum fuel impacts are encountered, as illustrated in figure 3. The fuel complex shields certain areas as the angle of entry is increased. Usually, low-level attack is necessary only when low retardant volumes are being utilized.

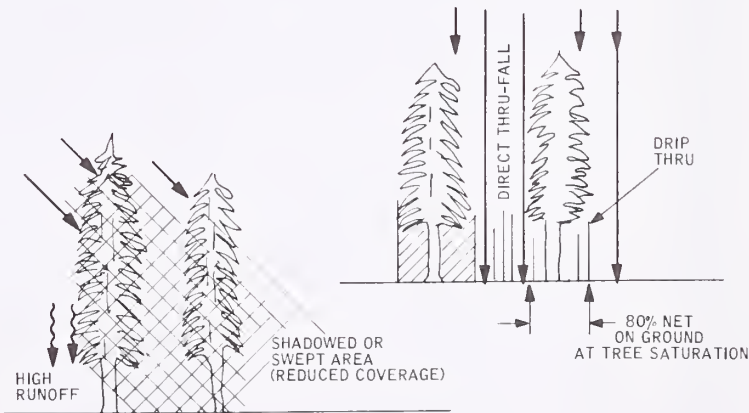


Figure 3.--Influence of drop height and retardant entry angle on overstory penetration.

The computers provide performance data for drop heights of 200, 300, and 400 feet (**above ground**). These heights were selected based on data regarding operational practices (a USDA Forest Service administrative directive enacted minimum drop height of 150 feet above the fuel

canopy for aircraft safety), safe drop heights (discussed in a later section of this paper), canopy height, and terrain considerations. To include additional heights would necessitate expanding the computer considerably. In addition, when considering performance and accuracy limitations, only slight differences occur for 100-foot versus 200-foot drop heights, but above 400 feet accuracy is drastically reduced.

To utilize the retardant coverage computer, the drop height is lined up with the retardant coverage (discussed later) and the maximum line length for each drop configuration read. The line length for any given drop height is a **maximum** predicted line length since these data were generated for low windspeeds (0-5 mi/h) and midrange drop speeds (usually 125 knots).

#### **Recommended Retardant Coverage Levels for Fuel Models**

Recommended retardant coverage levels were derived during the development of the airtanker performance guides (Swanson and others 1975). The coverage levels provide an important link between airtanker performance and the retardant required for a specific fuel/fire situation. In addition, in conjunction with pattern data they provide a basis for comparing the delivery performance of airtankers and for evaluating the effectiveness of airtanker operations (including tactics). The coverage levels recommended in the original airtanker performance guides

were keyed to the nine fuel models of the National Fire-Danger Rating System (Deeming and others 1972). Coverage-level values were based on the maximum useful retardant concentrations calculated by Rothermel and Philpot (1975). The feature of a retardant-film thickness was also incorporated, using the original concept of Grah and Wilson (1944) and by determining the capacities of various vertical fuel models (Swanson and others 1973). These modifications to the model were used to refine estimates of the maximum useful retardant concentrations and hence as a basis to assign recommended retardant coverage levels.

The 1972 National Fire-Danger Rating System (NFDRS) was updated in 1977 (Deeming and others 1977) to correct deficiencies and to incorporate new technology. The number of fuel models in the 1972 NFDRS was expanded from 9 to 20 to more adequately represent the fuels encountered in the United States. In keeping with the refined fuel model descriptions, Rothermel<sup>1</sup> updated earlier estimates of fire retardant requirements. The estimates were based on the maximum useful retardant, the coverage of dry retardant required to minimize fire spread and intensity, (additional retardant will be of little value). Utilizing this information and the original recommended retardant coverage levels as displayed in the airtanker performance guides, an abbreviated table (fig. 4) was derived for use with the retardant coverage

Recommended For:		
Coverage Level	Fuel Model <sup>1</sup> (1978 NFDRS)	Description
1	A, L, S	Annual and Perennial Western grasses; tundra
2	C, H, P, U E, R.	Tall grasses; Conifer (with grasses/forbs/needles and/or woody shrubs understory) Hardwoods (winter and summer)
3	K, F <sup>2</sup> , N, T	Light slash (conifer or hardwood); Intermediate brush (green); Sawgrass; Western woody shrubs
4	G	Shortneedle conifer (heavy dead litter)
6	D, Q, F <sup>2</sup>	Southern Rough; Alaska Black Spruce, Intermediate brush (cured)
Greater than 6	B, I, J, O	California mixed chaparral; Medium and heavy slash; High Pocosin
For creeping or smouldering fires, reduction of one coverage level may be considered.		
<sup>1</sup> Fuel models considered to be in flammable condition.		
<sup>2</sup> Coverage level requirements for intermediate brush depend on its stage of curing.		

Figure 4.--Recommended retardant coverage levels in gallons/100 ft<sup>2</sup> for the 20 fuel models described in the 1978 National Fire-Danger Rating System.

<sup>1</sup>Rothermel, R.C. 1978. Estimation of fire retardant requirements. Unpubl. rep. USDA For. Serv., Intermt. For. and Range Exp. Stn., North. For. Fire Lab., Missoula, Mont.

computers. Footnote 1 (to the recommended coverage levels shown in fig. 4) is based on the assumption that fuels are dry enough for the fire to spread. Under marginal burning conditions the retardant requirements shown in figure 4 are probably excessive. This is illustrated by the difference in retardant requirements for fuel model F where fuel condition (degree of curing) makes a significant difference in the retardant requirement (footnote 2 of fig. 4).

After determining the fuel model most appropriate for a given situation, the recommended retardant coverage level (in gallons/100 ft<sup>2</sup> or gpc) can be determined using the data in figure 4. The coverage level can then be used as a base-line value by which different tank and gating systems, release options, retardants, etc., can be compared. The behavior of the fire in any particular fuel situation must be used to temper or adjust selected coverage levels.

### Drop Configuration

In the airtanker performance guides, performance of an airtanker/tanking system in constructing retardant line was given in detailed "maximum line length/tank-opening delay tables." Line length data were generated using the Pattern Simulation Model (PATSIM) and flow rate data on the specific tank and gating system for various methods of release. The simulation model increments retardant flow rate and flies each increment to extinction, distributes the retardant in space, and transforms it into a ground distribution pattern. A series of computer runs including different drop combinations, drop heights, etc., was then made. The output data (simulated ground pattern distributions) were then digested, line lengths at various coverage levels determined, release intervals to maximize line lengths determined, and the detailed line length tables developed. These tables were in turn summarized in "Best Strategy Charts" to allow quick identification of the drop configuration and release interval (delay) that gave the most efficient combination for any situation of coverage level, line length, and drop height.

The retardant coverage computer was designed to yield information similar to that of the Best Strategy Charts, with the exception that the maximum line length/release interval is given for each possible drop configuration, for coverage levels 0.5 to 6 gallons/100 ft<sup>2</sup> and drop heights of 200, 300, and 400 feet.

The retardant coverage computer was also designed to identify the type of releases possible for any given tank and gating system, yet was standardized in format so that one retardant coverage "sleeve or jacket" could be used for most aircraft/tank and gating systems. The format and layout shown in figure 5 lists all drop combinations (both trail and salvo) and covers most aircraft systems in use. The nomenclature for the door and trail combinations consists of the multiplication of two numbers; the first being the number of tanks or compartments released, the second being the number of releases making up the particular drop. For example:

*For a 4x2 door combination, where: 4 denotes four compartments or tanks are released at once, and 2 denotes two releases of four compartments were made.*

Line Length (ft)		Delay (s)	
Door Combinations (No. of tanks x No. of releases)	1x1	210 0	Trail Door Safe Drop Ht.
	1x2	485 1.4	
	1x3		
	1x4	1035 1.4	
	1x6		
	1x8		
	2x1	305 0	
	2x2	640 1.7	
	2x3		
	2x4		
	3x1		
	3x2		
Trail Door (Chutes)	4x1	395 0	
	4x2		
	6x1		
	8x1		
Safe Drop Height (Ft.)	1x1	0 0	
	1x2		
	1x4		
	2x1	110 0	
	2x2		
	4x1	475 0	
	1x1	190 160	
	2x1	220 170	
	3x1		
	4x1	310 190	
	6x1		
	8x1		

Figure 5.--Retardant coverage computer layout providing door combination/line length and delay and safe drop height information. (This example is for a Hemet Valley/Aero Union tanked C119G-3E with gum-thickened retardant, coverage level 2, and a 200-foot drop height.)

The maximum line length (in feet) and delay interval necessary to attain that line length are shown adjacent to the door or trail combination through a slot in the retardant coverage computer sleeve. Hence, the number of combinations (door and trail) are easily determined by observing those combinations having line length/delay data. For example, in figure 5, the retardant coverage computer data (for the Hemet Valley/Aero Union tanked C119G-3E) indicates a four-compartment tank system with trail capability. (Line length data exist for 1x1, 1x2, 1x4, 2x1, 2x2, and 4x1 door combinations in addition to 1x1, 2x1, 2x2, and 4x1 trail door combinations.) The line length attainable for each of the drop/door combinations is adjacent to each combination. For other than salvo releases (all tanks at once), the delay or release interval is given in seconds. For the 1x4 door combination release shown in figure 5, 1,035 feet of line can be attained when the four compartments are released with a 1.4-second delay between each single compartment release.

The retardant coverage computer permits the quick determination of the best drop configuration and release to maximize the line length for a specific drop height, retardant type, and desired coverage level. Different drop configurations can readily be compared as can the interrelated effects of drop height and retardant type.

### Safe Drop Height

Retardant drops have the potential for injuring personnel on the ground. Large unbroken quantities of retardant may hit firefighters or may dislodge tops of trees, brush, logs, loose stumps, rock, etc., which can injure firefighters. Airtanker pilots and air attack specialists, working in populated areas or in the support of ground personnel, are constantly concerned about firefighter safety.

Recent accidents and incidents have caused managers to consider present operational practices in terms of both safety of the aircraft and firefighters on the ground. In the interest of aircrews a minimum drop height of 150 feet

above the canopy or highest obstacles has been administratively imposed (discussed previously). Large-capacity airtankers, generally having higher retardant flow rates, have also contributed to the mounting number of on-the-ground incidents and accidents. This growing concern led to an attempt to quantify "safe drop heights" so that they might be displayed in the retardant coverage computers.

Flow rate data, pattern data, and photographic data concerning retardant breakup for various airtankers were studied. The rate of deformation, breakup, and retardant cloud formation is a function of the drop volume and the flow or evacuation rate. Retardant breaks up more slowly from tank and gating systems having larger flow rates at comparable volume (produces greater vertical penetration) than from tanks with slow flow rates (such tanks have a greater capability to provide higher retardant coverage levels). An equation was derived that correlated the vertical penetration (safe drop height) with volume and flow rate. Although the data varied due to effects of tank and release geometry, etc., the relationship was satisfactorily used to define a lower limit of penetration for different tank and gating systems.

The vertical penetration was defined as the vertical distance below the aircraft where total breakup occurred. This is also the point at which forward trajectory and velocity stop. Figure 6 illustrates the point at which penetration is calculated. At drop heights less than the penetration value, the impact of the uneroded retardant can be expected to be hazardous, depending upon the situation.

Using the flow rate for each drop configuration and the derived relationship, a safe drop height can be estimated. The retardant coverage computer displays the safe drop height value for each drop or door configuration (fig. 5). Because the values do not change with coverage level for each salvo configuration, they are identical for all settings of the slide chart. Safe drop heights are identical for both gumlike and waterlike retardant. Although differences exist, they are so minor in comparison to effects of tank geometry that they are omitted. (Retardant type becomes an influence after the retardant is stripped from the central mass and during further breakup, cloud formation, and settling.)

For the example shown in figure 5 for the Hemet Valley/Aero Union tanked C119G-3E, the safe drop height in feet was displayed:

Door combination	Safe drop height (ft)
1x1	190
2x1	220
4x1	310

This means that a single drop (500 gallons) from less than 190 feet over the fuel complex may not break up and may endanger firefighters. Similarly, a salvo drop (4x1 of 2,000 gallons) does not completely break up until a penetration height of 310 feet is reached. Safe drop heights are quite high for this particular airtanker because it has one of the highest flow rates. Thus, the retardant coverage computer provides a quick reference and estimate of the safe drop height above the fuel under low wind conditions (0-5 mi/h). The minimum safe drop height, of course, decreases with increased wind as does the optimum drop height for retardant effectiveness.

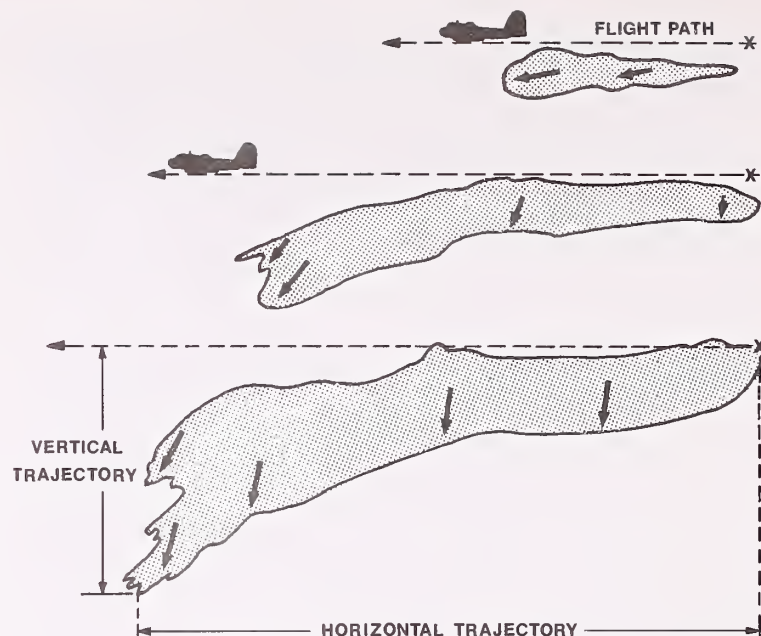


Figure 6.--Diagram showing the method for identifying and determining the penetration or vertical trajectory of retardant drop.

## INSTRUCTIONS FOR USE

Once the information provided by the retardant coverage computer/slide chart is fully understood, the mechanics of using it are very simple. A brief outline of the steps follows:

1. Select the appropriate computer for the aircraft to be used. This can be accomplished by identification of the type of tank and gating system, or by reference to the national airtanker number system. (The latter step should be taken to verify the appropriate slide chart has been selected.) If a coverage computer is not available for that specific airtanker, it may be possible to select one having similar performance if one possesses a thorough knowledge of the tank and gating system. (Table 1 lists airtankers by type of tank and gating system for which retardant coverage computers are available.)

2. Select the proper side of the retardant coverage computer for the type of retardant to be employed in the operations. This will be **GUM-LIKE** retardant (such as Phos-Chek XA, Gelgard, Tenogum, or gum-thickened Fire-Trol 931 [LC]) or **WATER-LIKE** retardant (such as Fire-Trol 100, unthickened Fire-Trol 931 [LC] or water.)

3. Select from the Recommended Retardant Coverage Level chart (one located on each side of the coverage computer) the appropriate coverage level for the fuel and fire situation. Modify the coverage level for unusual fire characteristics or behavior (for example, reduce the coverage level if the fire is creeping or smoldering) or based on experience if necessary.

4. Estimate the drop height limits:

- a. To assure aircraft safety in clearance of terrain features during the maneuver (150-foot minimum above canopy is an often imposed administrative limitation), and
- b. To protect ground personnel in close-support operations (the safe drop height will be verified after the best drop configuration is identified and may necessitate a change in drop height.)

Table 1.--Aircraft/tank and galing systems for which retardant coverage computers/slide charts are available

Type aircraft/ tank and galing system	Applicable volume	Numbers of aircraft having tank and galing system
	Gallons	
CDF/Hemet Valley tanked S2F	800	70, 71
CDF/Aero Union tanked S2F	800	72, 73, 74, 75, 76, 77, 78, 79, 80, 90, 91, 92, 93, 94, 95, 96, 100
Ralco tanked PV-2	1,000	38, 39
Reeder tank/Lynch Stol B-26	1,200	58
Canadair CL-215	1,400	All Canadair CL-215
Evergreen/Rosenbalm B-17'	1,800	22
Globe tanked B-17	1,800	04, 99
Black Hills tanked B-17	1,800	09, 12
Aero Union tanked DC-4/6/7	1,800-3,000	DC-4 02, 13, 14, 16, 18, 19 DC-6 54, 97 DC-7 32, 33, 35, 60, 61, 62, 66, 67, 115
W.A.I.G. tanked DC-4	2,000	113, 118, 119, 160
Hemet Valley/Aero Union tanked C119G-3E	2,000	81, 82, 86
Hawkins & Powers tanked C119G-3E	2,000	36, 87, 88, 134, 135, 136, 137, 138, 139, 140
Hawkins & Powers tanked PB4Y2	2,200	30, 121, 122, 123, 124, 126, 127
Black Hills tanked P2V-5	2,450	05
Black Hills/Rosenbalm tanked P2V-7	2,450	08, 11
Central Air Services DC-7	3,000	110
Transwest tanked DC-7	3,000	28
SIS Q/Rosenbalm tanked DC-6/7	3,000	20, 21, 44, 45, 46, 47, 48, 51
C-130 MAFFS	3,000	All C-130 Maffs

5. Align the desired retardant coverage level with the estimated drop height on the coverage computer and read the maximum length of line that can be expected for each alternate drop configuration (including trail drops). For other than salvo drops the required delay interval in seconds is adjacent to the line length.

6. Assess the line length that can be made with that needed for the particular operation, tactic, or strategy and select the best drop configuration.

7. Reevaluate the drop height limits in terms of the safe drop height for the selected drop configuration and adjust if necessary.

8. If unusual drop conditions exist, such as higher than normal wind conditions, consider selecting a higher retardant coverage level, lower drop height, or both (lower drop height for accuracy and performance, higher coverage level for increased retardant dispersion and aircraft safety margins).

9. Repeat steps 3-8 as adjustments are necessary (for example, as performance is observed in real-time fire operations).

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Slide chart computers have been developed to guide application of fire retardant from airtankers. The computers predict delivery performance for tank and gating systems on specific aircraft and recommend coverage levels for various fuel and fire situations. The devices also enable personnel to calculate safe drop heights, length of retardant line, and most effective drop configuration. The computers cover both gumlike and waterlike retardants and are available for many aircraft and tank and gating systems in operation.

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KEYWORDS: fire retardant, aerial delivery, tank and gating system, performance guides, retardant coverage levels, fuel models, drop height, release sequence, safety

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